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Type of Organization: College or University

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Project Title: Contaminated Sediment Resuspension in Duluth-Superior Harbor

Project Category: Contaminated Sediments

Rank by Organization (if applicable): 0

Total Funding Requested (\$): 154,100 **Project Duration:** 2 Years

Abstract:

This project will determine how susceptible contaminated sediments at two sites (Slip C and City of Superior WWTP) in Duluth-Superior Harbor are to resuspension. To achieve this objective, a new, innovative in-situ instrument, Sediment Imaging, Acoustic Doppler Velocity, Current and Concentration Profile (SI-ADV-CCP), will be developed, calibrated, and used to measure the rates of contaminated sediment resuspension for various intensities and causes of water motions, including harbor oscillations, ship passage, and storm events. To address the effects of sediment properties (e.g., bulk density, water content, organic fraction, soil indices, and size and settling velocity distribution) on resuspension, sediment cores will be taken and analyzed. Total mercury will be analyzed from water samples and sediment cores to assess the effect of resuspension on the release of contaminants into the harbor. The resuspension rate relationship obtained from the field measurements will be extended through controlled laboratory flume tests. The project outcomes are (1) the development of an in-situ instrument package for measuring rates and amounts of sediment resuspension in shallow water bodies and (2) the use of this package in determining the conditions for resuspension in Duluth-Superior Harbor. Regulatory agencies (MPCA and WDNR) have indicated that they will use these results for developing sediment remediation plans for the harbor area.

Geographic Areas Affected by the Project

States:

<input type="checkbox"/> Illinois	<input type="checkbox"/> New York
<input type="checkbox"/> Indiana	<input type="checkbox"/> Pennsylvania
<input type="checkbox"/> Michigan	<input checked="" type="checkbox"/> Wisconsin
<input checked="" type="checkbox"/> Minnesota	<input type="checkbox"/> Ohio

Lakes:

<input checked="" type="checkbox"/> Superior	<input type="checkbox"/> Erie
<input type="checkbox"/> Huron	<input type="checkbox"/> Ontario
<input type="checkbox"/> Michigan	<input type="checkbox"/> All Lakes

Geographic Initiatives:

<input type="checkbox"/> Greater Chicago	<input type="checkbox"/> NE Ohio	<input type="checkbox"/> NW Indiana	<input type="checkbox"/> SE Michigan	<input type="checkbox"/> Lake St. Clair
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Primary Affected Area of Concern: St. Louis River, MN

Other Affected Areas of Concern:

For Habitat Projects Only:

Primary Affected Biodiversity Investment Area:

Other Affected Biodiversity Investment Areas:

Problem Statement:

Knowledge of the conditions for and probability of resuspension of contaminated sediments are very important in assessing the feasibility of remediation in harbors. In addition, redistribution of contaminated sediments by resuspension, transport, and deposition processes effects the spatial extent of clean-up in a harbor. The Duluth-Superior Harbor along with the lower St. Louis and Nemadji Rivers has been designated an Area of Concern (AOC) due to the impairment of beneficial uses that includes restriction of dredging activities because of contaminated sediments (MPCA and WDNR, 1992). MPCA and WDNR recent studies have found that contaminant concentrations vary widely in the harbor. Several areas of elevated contaminants, hot spots, have been identified and ranked for further investigation, including Slip C in Duluth Harbor, Minnesota Slip, Hearing Island, City of Superior WWTP, and Hog Island inlet due to elevated levels of heavy metals (principally mercury, cadmium, lead, zinc), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), DDT metabolites, and toxaphene (MPCA 1997, Crane 1999, King 1999). While sediment remediation plans for some hot spots have been proposed, no assessment of how susceptible these sediments are to resuspension or their redistribution have been conducted.

Proposed Work Outcome:

In this contaminated sediment research program, in-situ measurements, chemical analysis and numerical modeling will be used to evaluate the conditions for and effects of resuspension under conditions of harbor oscillation, ship passage, and episodic storm event in Slip C of Duluth Harbor and at the City of Superior WWTP in Superior Harbor. The major outcome of this study will be information for assessing the susceptibility of sediment resuspension in Duluth-Superior Harbor.

Components of this proposed work are:

*** In-situ Resuspension Measurements**

An innovative, in-situ, instrument package, Sediment Imaging, Acoustic Doppler Velocity, Current and Concentration Profile (SI-ADV-CCP), will be developed to study resuspension. This instrument package consists of a mounting platform with three modules: (1) two underwater CCD video cameras (a zoom-out camera to guide instrument installation and measure bed elevation change and a zoom-in camera with image processing algorithms to measure particle size distribution and sediment settling velocity); (2) two Acoustic Doppler velocimeters (ADV), positioned at 3cm and 100cm above the bed, to measure three-dimensional, instantaneous water velocities, with pressure sensors to measure surface wave motion; and (3) an Acoustic Doppler Current Profiler (ADCP) for current measurements in the bottom boundary layer (about 1 cm above bed to about 150cm above bottom) and Optic Backscatter Sensors (OBS) to measure suspended sediment concentrations at five elevations from the bed up to 150 cm.

To determine resuspension rate, a control volume approach is used. Measurements by the SI-ADV-CCP provide mean and turbulent, vertical, sediment fluxes. The sediment fluxes at 3cm and 100 cm above the bed are determined from instantaneous and time average products of the instantaneous and mean velocities (from ADV) and instantaneous and

mean sediment concentrations (from OBS). The deposition flux is the product of particle settling velocity and sediment concentration, obtained from images, particle tracking, and OBS. Using these vertical sediment fluxes in the sediment mass conservation equation, assuming no net horizontal sediment transport (measure mean horizontal sediment flux at one location with ADCP and OBS), and measuring the bed elevation by the video camera, an estimate for the rate of sediment resuspension will be obtained. The critical shear stress can be estimated using the mean, horizontal turbulent shear stresses (from ADVs). A unique feature of the proposed instrument is not only to determine but also to visualize this dynamic process of sediment resuspension in the wave-current, bottom boundary layer.

*** In-situ Sediment Resuspension Measurements**

The SI-ADV-CCP instrument will be deployed in Slip C of Duluth Harbor and at City of Superior WWTP in Superior Harbor using the R/V Mudpuppy. The SI-ADV-CCP will record velocity, bottom current and concentration profiles, water level fluctuations, and images. Sediment cores with a depth of 60 cm will be also taken using a manually-driven, Livingston core. Water samples for suspended solids, turbidity, and chemical contents will be collected at the heights of 1m, 3m, and 7m above the bottom. In this study, resuspension rates under (1) seiche oscillation, (2) ship traffic, and (3) episodic storms will be investigated. The effects of fundamental periods of harbor and of motions driven by Lake Superior seiche on sediment resuspension will be examined. Resuspension due to ship passage will be investigated in the shipping channel. From historical data records in Duluth-Superior Harbor, storm events usually occur in early spring after ice-out and summer. The SI-ADV-CP is planned to be deployed in June 2001 and in April 2002 to record sediment resuspension due to episodic storms and the other conditions.

*** Laboratory Sediment Experiments**

To characterize the physical properties of sediment effecting resuspension, bed surface properties (bulk density, water content, organic fraction, soil indices, and size distribution) will be obtained with 1cm slices from undisturbed, sediment cores, collected in the field. Particle size distribution will be analyzed by the standard hydrometer test (ASTM, 1997) and compared with that obtained from image processing techniques.

A laboratory flume with a length of 50m will be used to examine resuspension under varying wave-current interaction conditions. The velocity and the concentration profiles will be measured using a Digital Particle Image Velcometer (DPIV) and OBS. The laboratory results will be compared with those obtained in the field to address the effects of control environments on sediment resuspension.

*** Sediment Chemistry**

Total mercury concentrations in suspended and bottom sediments (sediment cores) will be measured using oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry techniques (Wisconsin State Laboratory of Hygiene, Method 541.1. Suspended sediments (> 1.0 μm) will be collected on filter cartridges using trace metal clean techniques developed by the mercury research group in the UW-Madison Water Chemistry Laboratory. Concurrent measurements of suspended particulate matter concentration will allow calculation of suspended mercury concentrations on a mass (ng/g) or volume (ng/L) basis. The mercury analyses will be performed in a trace metal clean laboratory at the Wisconsin State Laboratory of Hygiene.

*** Other issues:** Transport of contaminated sediments will be studied in another project.

Project Milestones:

Dates:

Instrument Development and Calibration	10/2000
Instrument Deployment (summer)	06/2001
Analytical Chemical Results	10/2001
Data Analysis	12/2001
Instrument Deployment (spring)	03/2001
Laboratory Sediment Property Experiments	05/2002
Draft Report	08/2002
Final Report	10/2002

☐ Project Addresses Environmental Justice

If So, Description of How:

☒ Project Addresses Education/Outreach

If So, Description of How:

The results of this project will be used to assess the impacts of remediation on Slip C and City of WWTP in Duluth-Superior Harbor. In addition, the results will be disseminated through peer-reviewed publications and conference presentations. The instrument package can also be applied to other AOCs for examining resuspension of contaminated sediment.

Project Budget:

	Federal Share Requested (\$)	Applicant's Share (\$)
Personnel:	56,700	7,070
Fringe:	8,400	2,298
Travel:	8,000	0
Equipment:	10,000	7,000
Supplies:	7,000	0
Contracts:	20,000	0
Construction:	0	0
Other:	0	0
Total Direct Costs:	110,100	16,368
Indirect Costs:	44,000	4,122
Total:	154,100	20,490
Projected Income:	0	0

Funding by Other Organizations (Names, Amounts, Description of Commitments):

The funding for the proposed instrument is partly provided by the UW College of Engineering. The Research Development Instrument (RDI) Company will donate 1 ADCP for the field experiment. The investigators will also provide additional time, as needed, beyond the salary amount designated in the above budget.

Description of Collaboration/Community Based Support:

This project will be conducted under the direction of Professors John A. Hoopes, Chin Wu, and David E. Armstrong in the Civil & Environmental Engineering Department at the University of Wisconsin - Madison. Professors Hoopes and Wu will be responsible for the development and calibration of the instrument package, its deployment, and reduction/analysis/interpretation of the data; Professor Armstrong will oversee the collection, preparation, analysis, and interpretation of the sediment samples for mercury. Each of these investigators is directly involved with and committed to the completion of this research.

Field support will be needed from GLNPO for using the R/V Mudpuppy. Buoys and associated hardware will be provided by the UW Sea Grant Institute. The RD Instrument Company will provide acoustic doppler hardware if needed. Field work will be coordinated with MPCA and WDNR; they are looking forward to receiving the resuspension results and will use them in evaluating sediment remediation plans in the harbor.